NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A STATISTICAL EVALUATION OF MILITARY
CONSTRUCTION PROJECT COST ESTIMATES

by

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ninety percent.

These equations are derived through the use of statistical regression of the past eight years' Military Construction project's actual cost regressed on the project's authorized cost. A total of 1065 projects are compared and the resulting equations are assembled by Engineering Field Division (EFD) and by fiscal year.

In addition to the regression equations, an average project cost variation and a weighted cost variation is provided for each EFD. These variations can be used by the EFD's as trend indicators and measures of the overall effectiveness of the EFD's cost estimating practices.

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A Statistical Evaluation of Military Construction Project Cost Estimates

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ABSTRACT

The provision of accurate total construction cost estimates to the Congress is a continuing problem for the Naval Facilities Engineering Command. It is the purpose of this thesis to provide a series of equations which will reduce the variance of the actual total cost from the estimated total cost. When these equations are applied over the long run to all Military Construction projects, this variance could be reduced by approximately ninety percent.

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I. BACKGROUND

The problem of making accurate construction cost estimates goes back to antiquity. There have been many cost estimating methods and concepts developed over the years. Most of these were used until they were superceded by a method or combination of methods which led to more accurate estimates of the actual cost of a project. There is still no one cost estimating method or combination of methods that will produce 100 percent accuracy 100 percent of the time.

This problem, which continues to plague the construction industry, is due to the industry's inability to project the total impact of all of the factors combined on construction costs at some point in the future. These factors include such variables as inflation, inconsistent but acceptable estimating practices, varying local condititions, i.e., labor rates and the cost of materials, as well as the changing political make up of the Congress in the case of military construction.

The purpose of this thesis is to provide adjustment factors to assist in the preparation of more accurate estimates of the actual total costs of Military Construction (MILCON) projects prior to their authorization by the Congress. A review of the past eight years' actual costs of all closed-out Navy MILCON projects, including Bethesda National Naval Medical Center and Trident West, will be used to derive the individual adjustment factors for each Engineering Field Division (EFD) and one for Naval Facilities Engineering Command (NAVFAC) as a whole. A method for updating these factors will also be provided.

Chapter I will discuss both the problems associated with accurate construction cost estimating and the approach to a solution as proposed by this thesis. Chapter II will be a discussion of the major influences that have an effect on MILCON cost estimates. These include a discussion of the Congressional role in the MILCON funding process and NAVFAC and the EFD and their roles in the MILCON cost estimating process. Chapter III will be a detailed discussion of the analysis of the data. Discussed are the data and their sources, the methodology used to obtain the factors, and the results of the data manipulation including a summary listing of the findings. Chapter IV will discuss the conclusions and recommendations reached as a result of the research. Appendix A will be a detailed listing of the findings segregated by EFD. Appendix B will be a detailed listing of additional information obtained during the research. This information will be useful in a comparison of the EFD's MILCON project programs. Appendix C will be a condensed table listing specific student's t distribution values available to be used in future calculations by the EFD's and NAVFAC.

II. MAJOR ASPECTS OF THE MILITARY CONSTRUCTION PROCESS

There are several major aspects and perspectives of the MILCON process that require special attention. These include the roles of the Congress, the Naval Facilities Engineering Command (NAVFAC), the Engineering Field Divisions (EFD's), and the Facilities Acquisition and Construction Support Office (FACSO).

A. THE CONGRESS

In the Congress, the Military Construction (MILCON) Project funding process goes through four phases as depicted in Figure 2.1. These phases are presented in detail in Tables I through IV.

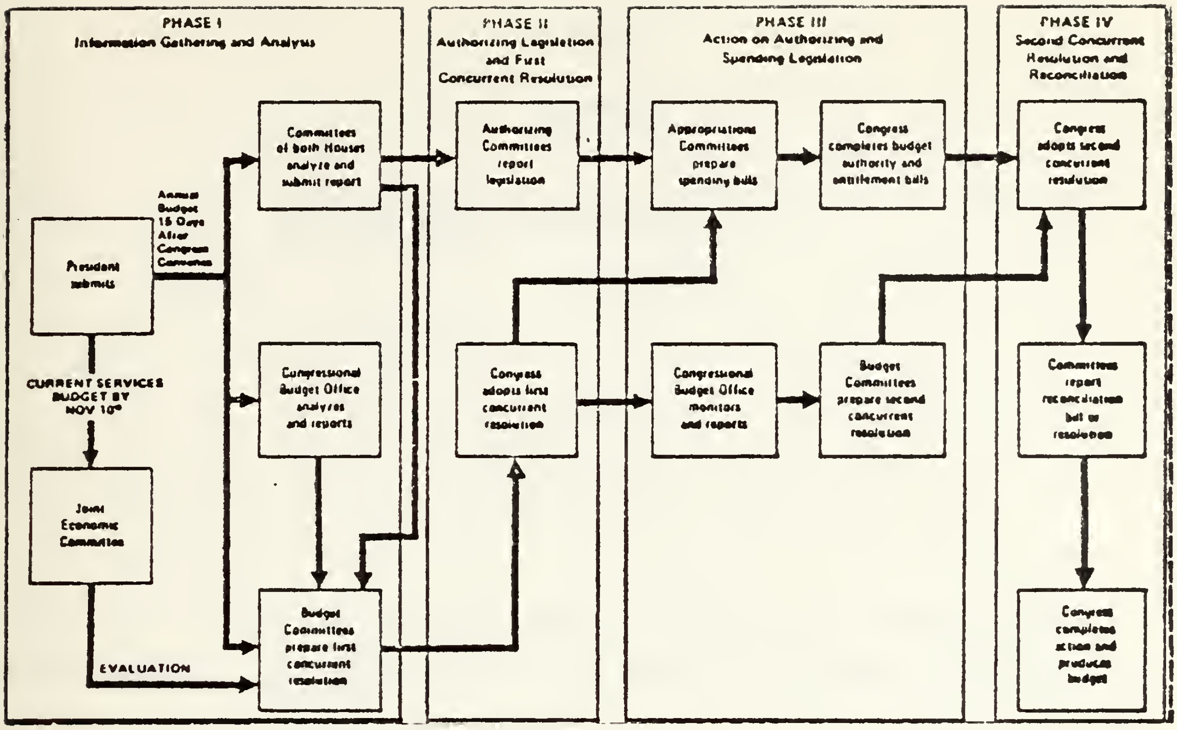

Figure 2.1 General Chronology of Congressional Budget Action

TABLE I

Phase I

10 November	President submits current services budget
31 December	Joint Economic Committee submits economic evaluation to budget committees
15th day after Congress convenes	President submits his budget
15 March	Committees and Joint Committees submit reports to budget committees
1 April	Congressional Budget Office submits report to budget committees
10 April	President submits budget amendments
15 April	Budget Committees report first concurrent resolution to their houses

TABLE II

Phase II

15 May	Committees report legislation authorizing new budget authority

TABLE III

Phase III

15 July	President submits additional budget amendments
No Deadline	Appropriations committees prepare spending bills
No Deadline	Budget committees prepare second concurrent resolution
7th day after Labor Day	Congress completes action on budget authority and entitlement bills

TABLE IV

Phase IV

15 September	Congress adopts second concurrent resolution
No Deadline	Committees report reconciliation bill or resolution
25 September	Congress completes action, brings congressional budget timetable to a close

Table I depicts the information gathering and analysis phase in detail. Table II describes the time period during which the authorizing legislation and the

TABLE V

Subcommittees of the Armed Services Committees, 95th Congress

House	Senate
Intelligence and Military Applications of Nuclear Energy	Intelligence
	Military Construction and Stockpiles
Research and Developement	General Procurement
Seapower and Strategic and Critical Materials	Arms Control
Investigations	Tactical Aircraft
Military Installations and Facilities	Research and Development
Military Personnel	General Legislation
Military Compensation	Manpower and Personnel

first concurrent resolution are passed. Table III is the time table for the Congressional actions on the authorizing and spending legislation. Table IV shows the final phase of the Congressional appropriations legislation action during which the second concurrent resolution and reconcilation are passed into law.

As shown in Table V, the MILCON Appropriations are handled in the House of Representatives by the Military Installations and Facilities subcommittee and by the Military Construction and Stockpiles subcommittee in the Senate.

These subcommittees review each submitted MILCON project separately. Due to the excellent reputation of these subcommittees with the rest of the Congress, their recommendations are seldom questioned. During Phase II each service head is called on to defend his program submission in detail. It is at this time that the need for accurate

cost estimates is imperative. If the subcommittee is confident that every effort has been made to develope an accurate estimate they are much more inclined to fund the associated project. [Ref. 1: p. A-19]

B. NAVAL FACILITIES ENGINEERING COMMAND

Naval Facilities Engineering Command is a sub-major claimant of the Naval Material Command whose responsibilities include the construction, maintenance, and repair of all Naval shore facilities. These facilities include all Navy-owned real estate and natural resources as well as all Naval shore installations.

C. ENGINEERING FIELD DIVISIONS

The first echelon below headquarters in the NAVFAC chain of command is the Engineering Field Division (EFD) level. There are six EFD's located in various locations to provide contractural jurisdiction over specific geographic regions as shown in Figure 2.2.

In the construction phase of operations, NAVFAC is responsible for the completion of each coonstruction contract in accordance with all plans and specifications. These contracts are administered by Resident Officers in Charge of Construction (ROICC's). A ROICC reports directly to the EFD in all contract matters. He is also normally assigned to the installation as the Public Works Officer and, as such, reports directly to the installation Commanding Officer. [Ref. 2]

NAVFAC and the EFD's are responsible for furnishing the technical expertise in the determination of the need for new construction through the Shore Facilities Planning and Programming System (SFPS), for ensuring activity compliance

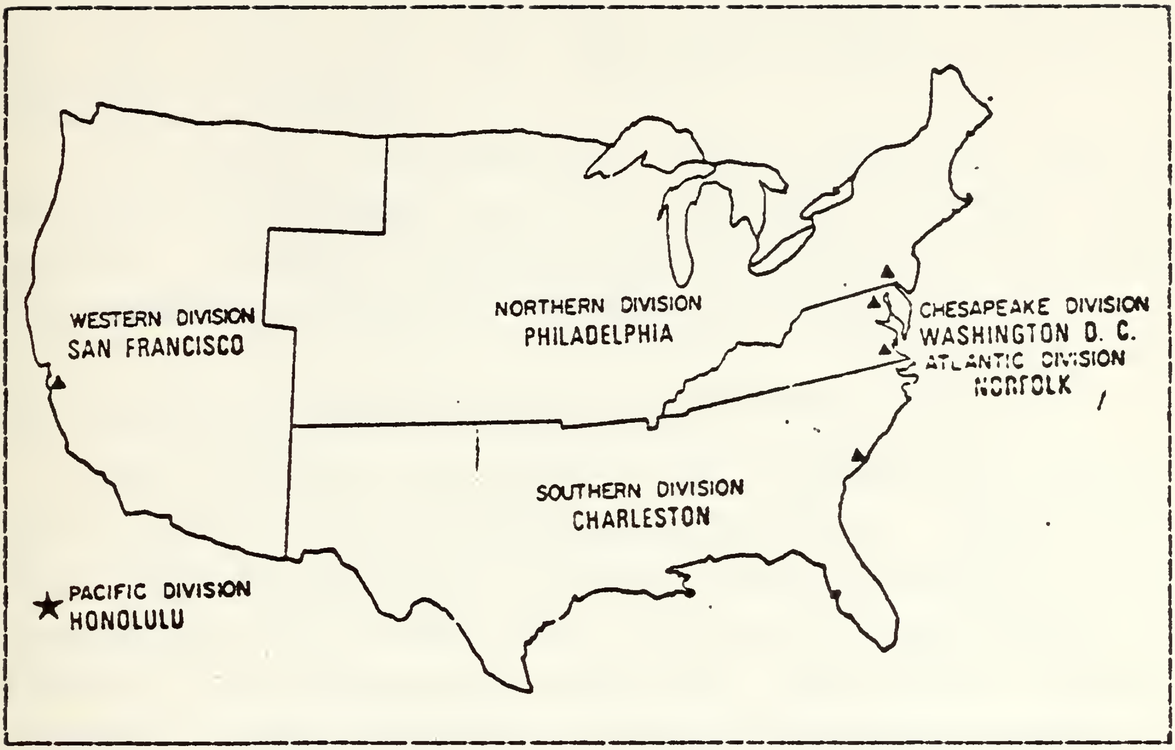

Figure 2.2 United States Showing Locations of Engineering Field Divisions

with instructions and criteria, and adequacy of cost estimates, as well as forwarding technical review comments to the appropriate level of the operational chain of command where decisions are made on funding and programming priorities. [Ref. 3:p. 245]

NAVFAC and the EFD's are also responsible for publishing planning guidelines and instructions to implement the SFPS, and providing engineering assistance where needed [Ref. 4].

D. MAJOR CLAIMANT

The activity major claimant is responsible for defining the activity's mission and projected base manning levels. Subsequent to developement of SFPS documents, the major

claimant reviews and validates the documents. The major claimant coordinates its subordinate commands' military construction programs.

The activity is responsible for initiating planning actions and documents and for obtaining assistance where needed. Projects for correction of facility deficiencies are normally initiated at the activity level.

E. FACILITIES ACQUISITION AND CONSTRUCTION OFFICE

The Facilities Acquisition and Construction Support Office (FACSO) is the accountant for NAVFAC. FACSO uses a fully automated system to maintain accurate accounts of all construction and acquisition contracts administered by NAVFAC. In addition to making all construction contract payments, FACSO also issues periodic management reports in support of the EFD's.

F. COST ESTIMATES

At present, cost estimates are prepared by various methods. Among them are the use of engineering performance standards, the use of the Shore Facilities Planning and Programming Manual , as well as the use of established estimating practices and the general experience of the estimator. Even with these established and accepted estimating practices, there is still a need to add an additional factor to adjust the estimate to take into account the variability of the EFD's estimating practices.

Estimates for construction projects must include the approximate cost of every item that enters into the work. Unit costs are based upon the cost of material in finished condition. These include material and labor costs as well as the contractor's indirect charges, and overhead costs.

Material requirements are developed from quantity surveys, and material prices are obtained from past records that are adjusted to the current date or from suppliers' and manufacturers' quotations and catalogs. Estimated labor costs are obtained from historical data as recorded by the Facilities Acquisition and Construction Support Office (FACSO), from recognized estimating publications, and are adjusted for current labor rates in the local area. The local minimum government construction contract labor rates are set by the Department of Labor in accordance with the Davis-Bacon Act. It is usually necessary for this adjustment also to reflect other local conditions and proposed methods of construction. The material and labor charges should also reflect any unusual risks that might be encountered because of working conditions or scarcity of material and/or labor. Furthermore, if these unusual risks warrant their inclusion as a special item in the estimate, they should be priced on a material and labor basis, if possible; otherwise, a lump sum charge is standard practice.

The estimated indirect charges of the contractor include all items normally recognized by generally accepted accounting practices as overhead. This total charge varies with the type and extent of the construction and the location of the project. The contractor's estimated profit is set at a maximum of six percent of the estimated construction costs including indirect and overhead costs [Ref. 5:p. 2-3]. The factors which are used to calculate the estimated contractor's profit vary from the amount of competition and the size of the project to the contractor's need for work to stay in business. [Ref. 5: p. 2-2]

G. TIME ELEMENTS

The normal MILCON project is of sufficient complexity and magnitude that the time required for the designer to prepare the thirty five percent design documentation often exeeds a year. This documentation comprises thirty five percent of the total design effort and includes preliminary cost estimates, outline specifications, preliminary drawings, and supporting data. The thirty five percent design documents are necessary in order to determine an approximate estimate of the cost and scope of the project. This project complexity and magnitude makes the use of civilian commercial expertise almost mandatory as most activity and EFD engineering departments are not equipped to produce highly specialized design. Most project documentation is provided by Architect/Engineering (A&E) service contracts. These contracts are awarded in accordance with NAVFAC P-68 which details the procedures by which they are to be solicited, negotiated, awarded, and administered and the mandatory time envelopes associated with each phase. The requirements associated with each phase of design contracts vary with the type and size of contract. [Ref. 2]

Following the initiation of the project at the activity level the A&E contract documentation must be prepared by either the activity, if it has the capability, or by the cognizant EFD. The time period for this evolution is two to four months. Subsequent to the completion of the design contract which had encompassed a total of four to six months and produced the thirty five percent design and project engineering documents (PED), the activity or EFD puts the information into the proper format for submission to its major claimant and simultaneously to NAVFAC. By this time almost a year has elapsed since the initiation of the project. After the project is inserted into the CNO's

budget submission and into the President's budget request, it takes almost another year for the Congress to complete its action and provide funding, as shown in Figure 2.1.

H. INFLATION

Over the past eight years, when inflation was approaching twenty percent at one point, these time delays of twelve to eighteen months could mean that a project's original estimated cost could have risen substantially faster than the standard ten percent inflation rate called for in the SFPS documentation. A comparison of these two inflation rates would appear to show that the SFPS inflation factor may be too low.

In fact, however, the use of the constant ten percent inflation factor does have a tendency to fully offset the effect of inflation (in the long run). While the total actual costs rise, the cost estimates have risen at ten percent which closely approximates the actual average inflation rate over the past five years, Therefore, there appears to be no need for an additional inflation factor to account for the long run effects of inflation.

Inflation has had a detrimental impact on the reliability of those estimates made two to three years prior to submission and an especially detrimental impact if the estimate was not updated immediately prior to submission to the CNO. Project managers and major claimants are aware of this effect and are requiring that all estimates be updated for inflation and any other forseeable changes immediately prior to submission to the CNO in an effort to ensure more accurate estimates.

III. ANALYSIS OF DATA

A. INTRODUCTION

The data on the 1065 projects over the last eight years were analyzed in an attempt to provide a better method for predicting the actual costs of a construction project using the original estimated costs as a predictor. The data were disaggregated by EFD as well as by fiscal year within each EFD. Linear regression analysis was used to obtain prediction equations. Equations for one EFD are examined in detail in this chapter with the detailed results from the other EFD's being presented in Appendix A.

B. DATA AND SOURCES

The data were obtained from FACSO Report number (MJBIDYL.CNTL (Act COST)) which lists each closed-out or completed construction project along with its authorized/estimated cost, and its actual cost, as well as its identification number, title of the project, and the activity at which it was constructed. The data obtained from FACSO were verified by comparison with the annual Composite 'As Enacted' Budgets provided by Congress to each EFD. These budgets list all MILCON projects separately for that fiscal year with a full explanation of the project and amount of funding authorized for it. The authorized amount in each case was found to be the same as the estimated cost and, therefore, the terms are used synonymously.

C. METHODOLOGY

The two actual and estimated costs for the projects were related through the use of linear regression analysis. Linear regression analysis can be simplistically defined as the fitting of a line to a plot of more than two related points by a method known as the least sum of squares. This method reduces the sum of the squared distances from each point to the line to a minimum and thereby provides a single linear equation which represents all of the plotted relationships [Ref. 6: p. 320].

The pairs of points are plotted using the actual cost as the dependent variable on the y coordinate and the authorized/estimated cost as the independent variable on the x coordinate. The resulting equation has the form:

$$Y=B0 + B1 \times Xi$$

where y is the expected actual cost of the proposed project, Xi is the authorized/estimated cost, Bo is the y intercept, and B1 is the slope of fitted line.

The accuracy of the fitted equations is denoted by the R^2 term. R^2 (Coeffecient of Determination) is defined as the proportion of the total variation of Y as explained by the fitted equation. The fitted equation will reduce the variation of the actual cost from the estimated cost by the amount of R^2 [Ref. 6:p. 423]. R^2 is a measure of the amount of variability of the dependent variable that is explained by the fitted equation and is expressed in the form of a number between zero and 100. A higher percentage indicates a better fit and a more useful equation.

The standard error of the coefficient is a measure of the accuracy of the fitted coefficients of an equation. The standard error of the coefficient measures the deviation of the coefficient from the expected coefficient. The smaller

the standard error the more exact is the fit of that coefficient of the equation.

One would not expect any fitted line to predict the cost of any new project with 100 percent accuracy. Therein lies the need for an interval around the expected value in which the actual cost will lie with some degree of certainty. The following prediction equation is used to derive such an interval:

$$y +/- t(1-a/2, n-2)\ (s) \sqrt{\frac{1}{n} + \frac{(Xo-\bar{X})^2}{\sum Xi^2 - (n\bar{X}^2)} + 1}\ .$$

[Ref. 7:p. 72]

The following terms apply to the preceeding equation;

$\bar{X}$ is the mean authorized project cost for that EFD;

n is the total number of projects used in the regression (see Appendix A);

t is described as a student's t distribution with n-1 degrees of freedom. The level of certainty is selected at this point as it is needed to determine the appropriate t value (See Appendix C for Specific t values);

s is described in general as the standard deviation of the residuals (or the normal or expected distance the plotted observations lie form the fitted line);

Y is the figure used to denote the new or expected value of the actual cost;

a (alpha) is the significance level (.05);

Xo is the estimated cost of the new project provided by the EFD;

Xi^2 is the sum of the individual authorized costs squared.

The interval obtained from the above equation is the range in which the actual cost (Y) will fall with a given certainty or probability. The certainty or probability is entered into the equation via the t value provided by Appendix C. The specification of a specific probability is left to the user. The interval width can be controlled by an applicable rule of thumb that states that the smaller the probability used, the narrower the interval will be and vice versa.

D. RESULTS

Figure 3.1 is a plot of Chesapeake Division's fitted line and the prediction interval associated with an (a) of .05. This figure is represetative of the other EFD's as well as Bethesda and Trident West.

1. Fitted Line

. The fitted line for Chesapeake Division with 77 observations over six years is

$$y = 1.6592 + .9307 \times \text{Authorized}$$

with standard deviations for Bo = 23.05 and for B1 = .0126.

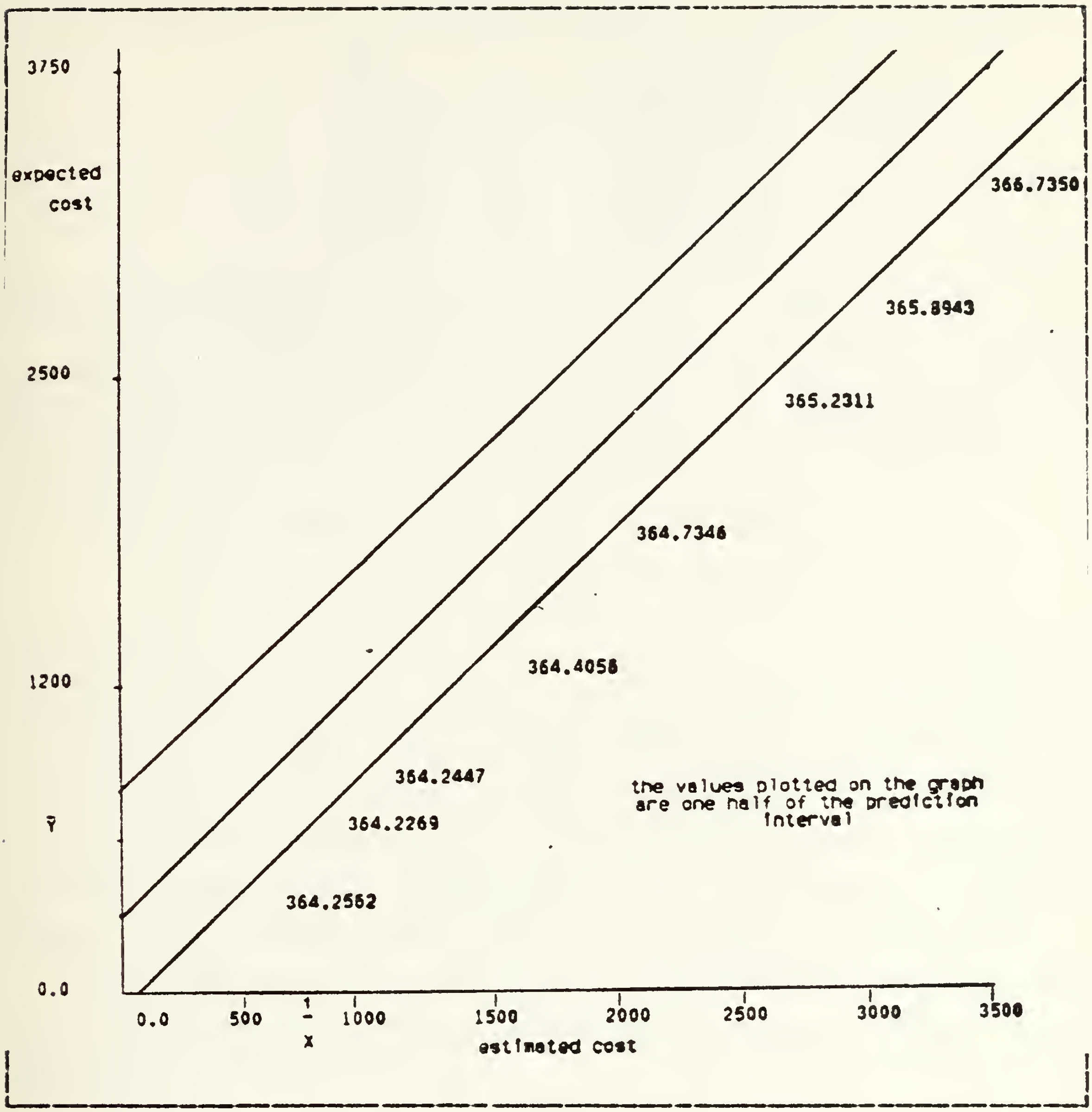

Figure 3.1 Detailed Plot of Chesapeake Division Fitted Line and Prediction Interval

2. Prediction Equation

The prediction equation for Chesapeake Division is

$$Y \pm (1.98)(182.77)\sqrt{\frac{1}{77} + \frac{(Xo - 771)^2}{58022190 - (77)(771)^2} + 1}$$

which results in the following ranges at selected points:

Xo		Interval
500	+/-	364.2516
771	+/-	364.2269
1000	+/-	364.2446
1500	+/-	364.4056
2000	+/-	364.7322
2500	+/-	365.2310
3000	+/-	365.8943
3500	+/-	366.7235

These ranges are graphically depicted in Figure 3.1.

The regression equations have been calculated for each EFD as well as Bethesda and Trident West and are presented in a summary form in Table VI and as an aggregate in Appendix A.

The fitted equation for the entire data set is

$$Y = 166.45 + .08412 \times \text{Authorized}$$

and produced an R^2 of only 26.42 percent. The low R^2 is due to the difference in the mean sizes of the normal MILCON projects and those mean sizes found in the Bethesda and Trident West construction project packages. When these two construction packages are introduced into the regression analysis their means distort the total data base to such an extent that a meaningful fitted line cannot be obtained .

The removal of the Bethesda and Trident West data from the regression analysis produces the following NAVFAC fitted equation

$$Y = 54.735 + .8657 \times \text{Authorized}$$

and

$$R^2 = 89.69 \text{ percent.}$$

This equation is useable by NAVFAC to predict the actual cost of a proposed project and, if used over the long run, will tend to reduce the estimating variance to near ten percent as the equation is capable of explaining only 89.69 percent of the variations of the present actual costs.

TABLE VI

Summary of Regression Equations

Naval Facilities Engineering Command

Actual = 54.735 + .8657 x Authorized

Chesapeake Division

Actual = 1.6592 + .9307 x Authorized

Atlantic Division

Actual = 31.049 + .7342 x Authorized

Northern Division

Actual = 12.225 + .9492 x Authorized

Southern Division

Actual = 2.02 + .8944 x Authorized

Western Division

Actual = 41.657 + .9575 x Authorized

Pacific Division

Actual = -1.093 + .8887 x Authorized

Figure 3.2 is the plot of all the EFD's and Bethesda and Trident West's fitted lines which graphically illustrate the above comments along with the effect of the inclusion and removal of the Bethesda and Trident West data.

A review of the R^2's for each EFD, provided in Appendix A, reveals that the Atlantic Division's overall R^2 is only 76.65 percent which is ten to fifteen percent lower

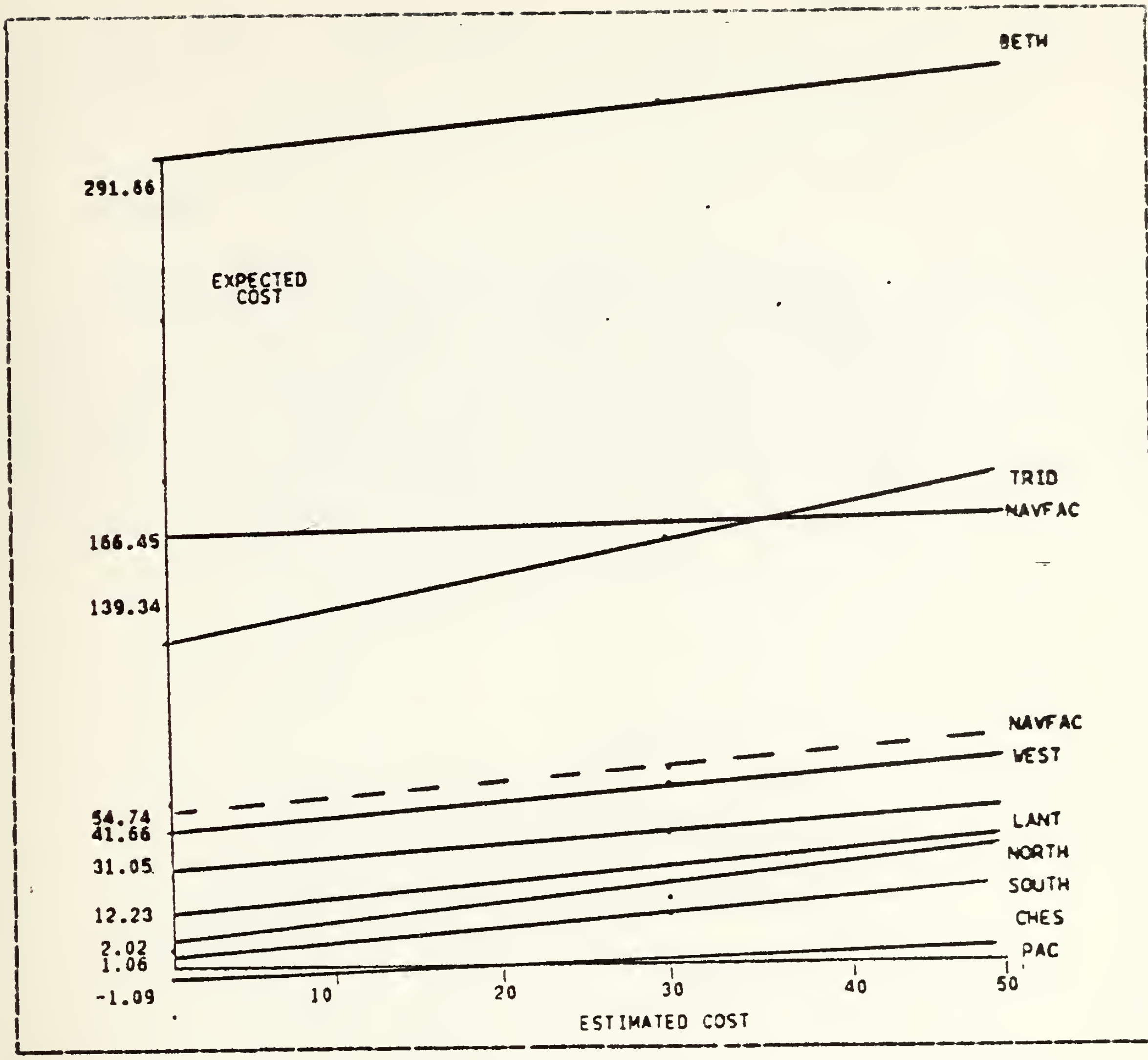

Figure 3.2 Plot of All Fitted Equations Including Bethesda and Trident West

than the other EFD's. Closer examination of the fiscal years' R^2's indicate that in FY1979 an R^2 of only 69.9 percent was realized. This aberration is due to the occurance of several large variances within the seventeen projects of that year. The causes of these variances are not known but due to their clustering in a single year would indicate an estimating problem or some other unusual problem

in that year. The removal of the FY 1979 data from the regression raised the overall Atlantic Division R^2 to 78.32 percent.

E. SUMMARY

Through the use of regresssion analysis, fitted equations for each EFD and NAVFAC as a whole were derived. Using these equations and the given prediction interval equation, an estimate of a prediction interval on actual cost of a proposed project can be derived with any desired degree of confidence.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

The conclusion drawn from the derived equations is summed up in the NAVFAC equation. The NAVFAC equation can be interpreted to mean that the data are linearly related to such an extent that 89.69 percent of the variability of the actual costs in the past eight years' NAVFAC MILCON projects can be explained by their estimated/authorized costs. This statement does not include the two special cases of Bethesda and Trident West.

With the overall Atlantic Division R^2 being 76.65 percent, which is ten to fifteen percent lower than any other EFD, there appears to be the possibility of a special estimating problem that is peculiar to Atlantic Division. The presence of the wide variations between the actual costs and the estimated costs would indicate that there may be a problem. However, there is also the possibility that the estimates were the best possible but the contracts themselves may have had peculiar problems and, hence, created cost problems. Due to the special problems that Atlantic Division appears to have, as indicated by the low R^2 values shown in Appendix A, it can be concluded further study is necessary.

B. RECOMMENDATIONS

At the close of each year, those projects that have been closed out by each EFD during that year should be added to the bottom of that EFD's data base and a like number removed from the top. This procedure will provide a data base of a

constant size that will not become too large to handle or too small to provide an accurate regression. Following insertion of the new projects, the regression analysis should be repeated and the results reviewed in the same manner as previously discussed. The effect of the application of the fitted equations will not be evident until projects that have been estimated using these factors are closed-out and their actual costs compared with their estimated costs.

It is noted that all of the slopes (B1's) in the regressed equations are less than 1.0 which is indicative of a consistent shrinkage of the estimated to the actual cost of the project. This reduction appears to be due to a systematic overestimation of all projects. This overestimation may be attributable to an attempt to offset the effects of inflation or to ensure that the size of the contingency fund is sufficient to cover all circumstances. A review of the past five years' inflation would indicate that the average annual inflation rate is approximately ten percent. With NAVFAC P-448 [Ref. 5] calling for a ten percent inflation factor to be used consistently in estimating, inflation should not be a factor in the variance from the authorized/ estimated cost. However, the slopes would indicate the ten percent factor is unnecessarily high. Consequently, there is a possibility that the inflation factor in P-448 should be adjusted. This possibility and the size of the adjustment will require further study.

A second possible explanation for the shrinkage is the size of the contingency or management reserve factor used in the current estimating process. At present, NAVFAC P-448 allows for ten percent of the construction costs to be added as a contingency factor. It would appear that the construction cost estimates are of sufficient accuracy so as

to largely alleviate the need for a portion of the contingency funding. This possibility and the size of the possible adjustment also will require further study.

Upon completion of the data manipulation and linear regression process, it was noted that Atlantic Division appears to have had some special problems but, overall, the EFD's and their ROICC's have consistently brought their MILCON projects to completion below the estimated cost. This speaks highly of their estimating, managerial, and administrative skills. The indication of consistent overestimation is the basis for the recommended studies into the possibility of the reduction of the inflation and contingency factors presently used in MILCON cost estimating. More accurate estimates would conceivably improve the NAVFAC credibility with the Congress which, among other benefits, could generate more favorable considerations for the MILCON program in general.

APPENDIX A

EFD EQUATIONS

This appendix is designed to provide an aggregate of the data derived from the regressions of the individual EFD data.

Listed are:

1. The names of the EFD's on which the data were obtained
2. The fitted equation for each EFD and each fiscal year in each EFD
3. The sum of the authorized/estimated costs squared
4. The standard deviation of the residuals from the fitted line
5. The number of projects used in the regression analysis
6. The resulting R^2

EFD	FITTED EQUATION	SUMM SQUARES Σx^2	STD DEV OF RESID (s)	#OBS	R^2 (n)
NAVFAC	54.735+.8657*AUTH	15178549000	478.64	999	.8969
CHESEPEAKE DIVISION		58022190			
OVERALL	1.6592+.9307*AUTH		182.77	77	.9864
74	13.160+.9902*AUTH		245.31	18	.9700
75	-20 +.9101*AUTH		71.12	12	.9923
76	69.8+.6640*AUTH		70.05	13	.9784
77	-11.5+.9150*AUTH		47.87	15	.9998
78	6.87+.8770*AUTH		60.60	12	.7403

79	-120+1.205*AUTH	59.85	18	.9981

SOUTHERN DIVISION		3133099000		
OVERALL	2.02+.8944 *AUTH	406.14	214	.9140
74	73.77+.8928*AUTH	337.9	72	.9487
75	-4.41+.9472*AUTH	513.9	67	.9255
76	96.22+.5924*AUTH	371.02	40	.7464
77	17.48+.7468*AUTH	209.42	30	.9107
78	29.22+.7571*AUTH	160.05	21	.7596
79	29.29+.9107*AUTH	58.33	11	.8596

ATLANTIC DIVISION		1737286000		
OVERALL	31.049+ .7342*AUTH	414.68	183	.7665
74	-12.122+ .9876*AUTH	285.24	53	.9737
75	-91.99 + .9055*AUTH	332.15	38	.9090
76	36.59 + .7029*AUTH	193.80	39	.9866
77	69.792+ .6376*AUTH	200.44	22	.9956
78	53.273+ .6244*AUTH	121.56	24	.9639
79	393.18 + .0220*AUTH	689.70	17	.6990
80	CANNOT REGRESS ON ONLY 2 OBSERVATIONS			

NORTHERN DIVISION		1991578000		
OVERALL	12.225+ .9492*AUTH	264.42	125	.9464
74	58.441+ .9874*AUTH	251.53	29	.9750
75	19.653+ .8182*AUTH	266.53	21	.9215
76	51.404+ .9503*AUTH	350.61	34	.9296
77	9.075+ .8739*AUTH	121.44	20	.9235
78	11.028+ .8214*AUTH	49.33	11	.7982
79	-75.282+1.0948*AUTH	52.59	6	.9931
80	35.416+ .8310*AUTH	38.21	4	.9395

PACIFIC DIVISION		2347655000		
OVERALL	-1.093+ .8887*AUTH	331.16	128	.9281
74	51.869+ .8851*AUTH	219.33	42	.9680

75	-32.611+1.0145*AUTH	136.52	25	.9896
76	50.090+ .7848*AUTH	549.98	14	.8862
77	-124.030+ .9394*AUTH	499.01	22	.8792
78	2.232+ .7596*AUTH	190.79	16	.9478
79	-70.86+1.0196*AUTH	111.66	7	.9730
WESTERN DIVISION	5388709000			
OVERALL	41.657+ .9575*AUTH	596.5	303	.8593
74	26.770+1.1800*AUTH	570.33	70	.8085
75	83.055+ .9045*AUTH	421.43	69	.9477
76	59.004+ .7797*AUTH	147.73	68	.9683
77	46.428+ .7685*AUTH	291.95	49	.9528
78	-8.6824+ .9699*AUTH	109.67	33	.9660
79	-36.780+1.0619*AUTH	68.53	14	.9565
TRIDENT WEST	4365602000			
OVERALL	139.34+ .8527*AUTH	574.51	44	.9809
74/75	242.68+ .8398*AUTH	941.30	12	.9842
76	36.936+ .8454*AUTH	238.33	14	.9652
77	-163.65+1.0594*AUTH	218.72	10	.9758
78	-128.18+1.1912*AUTH	349.54	8	.9708
BETHESDA HOSPITAL	323362239			
OVERALL	291.66+ .868*AUTH	595.20	7	.9880

APPENDIX B

MEANS AND AVERAGES

The 'mean authorized' figure is the average of the authorized amounts for all projects in that EFD.

The 'mean actual' figure is the mathematical average of the actual costs for all projects in that EFD.

The 'average percent shrinkage or growth' in the EFD is the mathematical average of the percentages of shrinkage or growth found in each project in the individual EFD. A project is said to shrink if the actual cost is less than the authorized amount and is said to grow if the actual cost is more than the authorized amount.

The 'average weighted variance' is a comparison of the total authorized amount for all fiscal years and total actual cost expressed as a percentage of the total authorized amount for that EFD.

==

ATLANTIC DIVISION

MEAN AUTHORIZED 1075. MEAN ACTUAL 877.5

AVERAGE 15.096 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 22.529 PERCENT SHRINK

==

CHESAPEAKE DIVISION

MEAN AUTHORIZED 771. MEAN ACTUAL 718.5

AVERAGE 9.674 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 7.268 PERCENT SHRINK

==

NORTHERN DIVISION

MEAN AUTHORIZED 821. MEAN ACTUAL 791.4

AVERAGE 3.567 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 3.732 PERCENT SHRINK

==

PACIFIC DIVISION

MEAN AUTHORIZED 1010. MEAN ACTUAL 893.6

AVERAGE 10.027 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 13.064 PERCENT SHRINK

==

SOUTHERN DIVISION

MEAN AUTHORIZED 1037. MEAN ACTUAL 929.2

AVERAGE 7.846 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 11.570 PERCENT SHRINK

==

WESTERN DIVISION

MEAN AUTHORIZED 1008. MEAN ACTUAL 1006.2

AVERAGE 2.172 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 0.136 PERCENT SHRINK

==

TRIDENT WEST

MEAN AUTHORIZED 2348. MEAN ACTUAL 2138.5

AVERAGE 4.192 PERCENT GROWTH IN THIS EFD

AVG WEIGHTED VARIANCE 9.803 PERCENT GROWTH

==

BETHESDA

MEAN AUTHORIZED 3766. MEAN ACTUAL 3524.0

AVERAGE 0.079 PERCENT SHRINKAGE IN THIS EFD

AVG WEIGHTED VARIANCE 6.876 PERCENT SHRINK

==

APPENDIX C

SELECTED STUDENT'S T DISTRIBUTION VALUES

The values listed are those specific Student's t distribution values applicable to the ninety, ninety-five, and ninety-nine percent prediction intervals. The n values listed are of such size so as to encompass the numbers of projects found in the EFD's and NAVFAC as a whole.

1-a/2	.95	.975	.995
n			
60	1.671	2.000	2.660
120	1.658	1.980	2.617
inf	1.645	1.960	2.576

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